RESEARCH DEPARTMENT

THE EFFECTS OF BUILDINGS AND TREES UPON THE PROPAGATION OF WAVES IN THE U.H.F. AND V.H.F. BANDS

Report No. K-162

(1963/39)

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SUMMARY

This report describes a series of measurements carried out to assess the magnitude of the field strength attenuation or 'shadow loss' produced at ultra high frequencies (u.h.f.) by both buildings and trees. Where practicable, corresponding assessments have been made on Band I and Band III transmissions for comparison. It is concluded that the shadow loss caused by buildings on Band V frequencies may be estimated by the application of Fresnel optical diffraction theory. This theory is not directly applicable to the lower frequency bands since building dimensions are not sufficiently large with respect to the wavelength of the transmission.

The additional shadow loss due to tree foliage in early autumn is small in comparison with the loss caused by the defoliated trees in winter. Further measurements are required in the late spring to determine whether the autumn results are fully representative of trees in leaf. Subjective viewing tests are necessary to establish the magnitude of any picture flutter due to the effect of wind in foliage.

1. INTRODUCTION

It is well known that the variations of field strength due to terrain features, and in particular to the presence of buildings and trees, are much greater at u.h.f. than in the v.h.f. bands. This is clearly shown in Fig. 1, which shows three field strength records obtained during identical cruises over a relatively flat area of terrain. These records are discussed in more detail later, but it may be seen that the overall scatter of field strength measurements increases from 9 dB on Band I to 33 dB on Band V. The investigation described below is confined to two aspects of shadow loss, namely that caused by buildings, and that caused by trees.

2. GENERAL

The field strength of a transmission existing at any receiving point may be considered as the vector sum of all the rays incident on the receiving aerial. In open country these will in general comprise a direct ray and one ground-reflected ray only, but in built-up and wooded areas at u.h.f. a more complicated situation arises, particularly where the direct ray is attenuated due to the receiving aerial being in shadow.

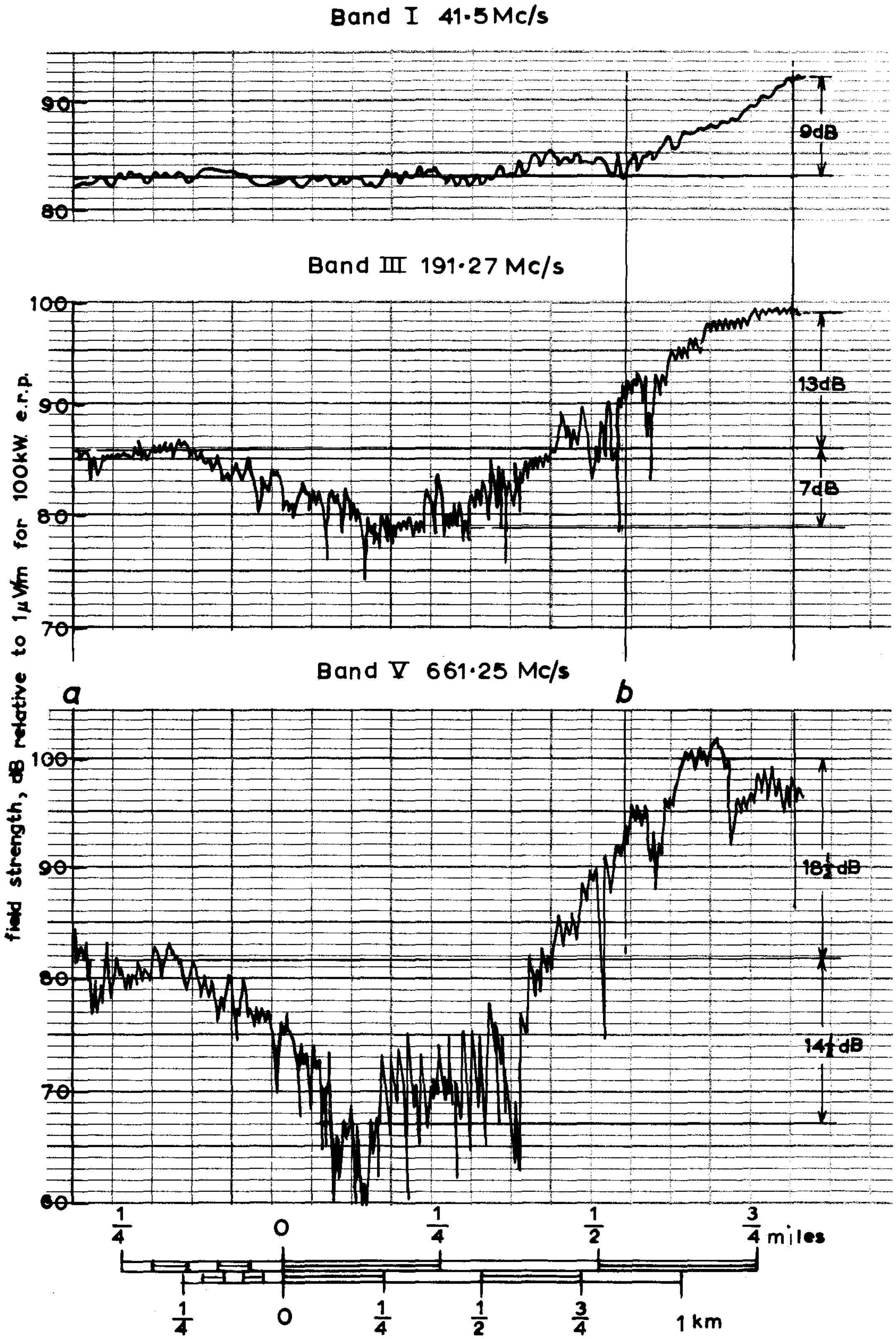

Fig. 1 - Frequency-comparison cruises on A.243 road

Receiving aerial height 30 ft (9·1 m) a.g.l.

In such instances the resultant field strength measured will be dependent upon the horizontal radiation pattern (h.r.p.) of the receiving aerial. For this reason all measurements were obtained using aerials representative of those likely to be used by domestic viewers.

To establish quantitatively the shadow loss caused by buildings, the following requirements must be satisfied:-

(a) Any shadow loss measured must be attributable to one specific building. Thus the building being investigated must be appreciably higher than any other building in its vicinity on the same bearing from the receiving point.

(b) It must be possible to measure or to estimate the field strength existing in the area in the absence of the building; hence the local terrain must be flat and open.

(c) Free access must be obtainable to a sufficient number of points in the shadow zone. This implies that the roads in the area of measurement must be sufficiently free of traffic and of overhead obstructions (e.g. trees and telephone lines) to enable the measurements to be obtained. In view of the great range of height gains obtaining in built-up areas, it was considered desirable to use receiving aerials at a standard height of 30 ft (9·1 m) above ground level (a.g.l.) for all measurements.

In the event, the above requirements proved very hard to satisfy, with the result that the shadow regions behind only two buildings were fully investigated, although a few measurements were obtained at other sites.

3. EQUIPMENT

As stated above, it was considered appropriate to use receiving aerials representative of those which might be used by domestic viewers. The Band V aerial was a three-element Yagi with screen reflector, whose beamwidth was ± 25° (to -3 dB points). The Band III aerial was a three-element Yagi, and for Band I an 'H' aerial was used. Measurements on Bands III and V were obtained with mobile receivers previously used on these frequencies and described elsewhere.[1]

4. TRANSMISSION CHARACTERISTICS

These are as tabulated below, the sound channel being measured in each instance.

TABLE 1

BAND	TRANSMITTER	TRANSMITTING AERIAL HEIGHT ft	m	FREQUENCY Mc/s	POLARIZATION	E.R.P. kW	MODULATION (SOUND CHANNEL)
I	Crystal Palace	425	130	41·5	V.P.	42	a.m.
III	Croydon	175	53	191·25	V.P.	30	a.m.
V	Crystal Palace	690	210	661·25	H.P.	25	f.m.

In many of the places visited the true effective radiated power (e.r.p.) of the Band V transmitter will be substantially different from that given in Table 1 because of the vertical radiation pattern (v.r.p.) of the transmitting aerial. Since, however, comparatively small areas are investigated at each site, this is not significant. Because the three transmitting aerials are at different heights, and since transmissions originated from two transmitter sites, no attempt was made to compare actual field strengths existing at any place on different frequencies.

5. DIFFRACTION LOSS DUE TO BUILDINGS

5.1. Theory

The method of Huyghens applied to optical diffraction past a straight edge results in the following expression for the received field E in terms of Fresnel integrals.

$$\frac{E}{E_0} = a - jb$$

where E_0 is the value of field with the straight edge removed.

$$a = \left(\frac{1}{2}\right)^{\frac{1}{2}} \int_v^{\infty} \cos\frac{\pi v^2}{2} dv = \left(\frac{1}{2}\right)^{\frac{1}{2}} \int_0^{\infty} \cos\frac{\pi v^2}{2} dv - \left(\frac{1}{2}\right)^{\frac{1}{2}} \int_0^{v} \cos\frac{\pi v^2}{2} dv$$

$$= \left(\frac{1}{2}\right)^{\frac{1}{2}} \left[\frac{1}{2} - C(v)\right]$$

Similarly

$$b = \left(\frac{1}{2}\right)^{\frac{1}{2}} \left[\frac{1}{2} - S(v)\right]$$

where $C(v)$ and $S(v)$ are standard forms of the Fresnel integrals, which have been tabulated.[2]

The parameter v may be expressed as

$$v = s\left(\frac{2d}{d_1 d_2 \lambda}\right)^{\frac{1}{2}}$$

or if $d_1 >> d_2$

$$v \simeq s\left(\frac{2}{d_2 \lambda}\right)^{\frac{1}{2}}$$

where the symbols refer to the diagram in Fig. 2.

Note that s represents the distance of the edge of the obstacle from the plane containing transmitting and receiving aerials, as measured along the wavefront

at this point. Since the distances are sufficiently great for the wavefront to be considered plane, s may be expressed as a height, and this may be considerably less than the actual height above ground level of the obstacle. The magnitude of s will be a function of the distances of transmitting and receiving aerials from the obstacle and of their respective heights above the ground plane on which it is situated.

The relationship between v and the field strength ratio E/E_0 is represented in logarithmic form in Fig. 3.

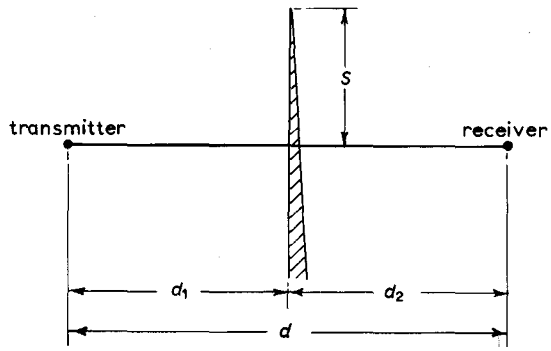

Fig. 2 - Diagram illustrating knife-edge obstruction between transmitter and receiver

Fresnel diffraction theory is only strictly applicable if:-

(a) The wavelength is small compared to the dimensions of the obstacle. This will in general be true for Band V, but not for Band I.

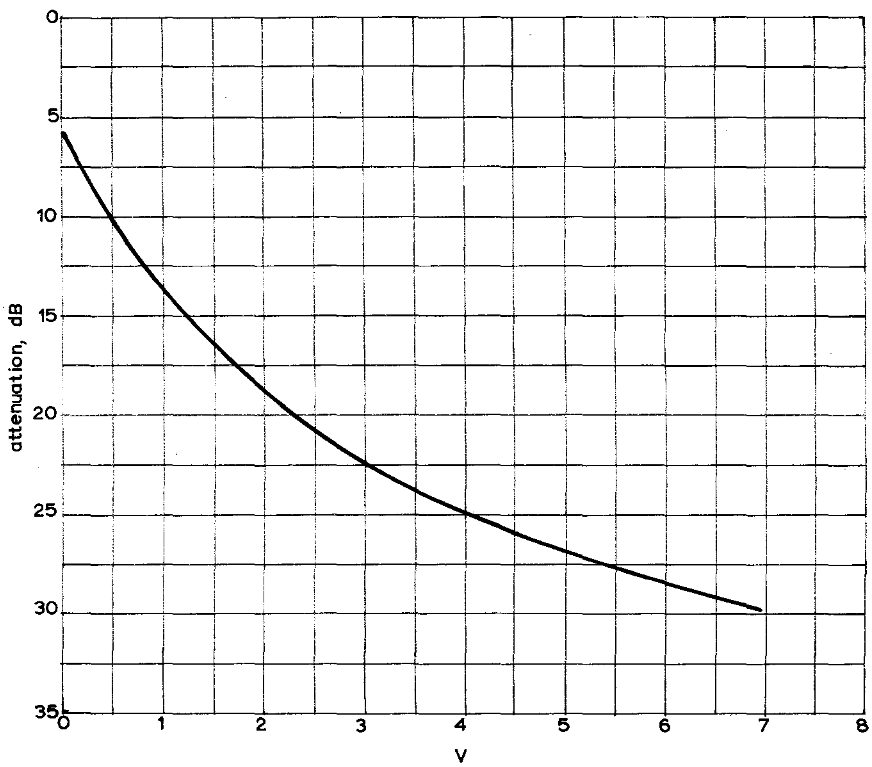

Fig. 3 - Relationship between parameter v and attenuation in decibels

$$\text{Ordinate} = 20\ \log_{10}\left|\frac{E}{E_0}\right|$$

$$= 20\ \log_{10}\left(\frac{1}{2}\right)^{\frac{1}{2}} \left|\int_v^\infty \cos\frac{\pi v^2}{2}\,dv - j\int_v^\infty \sin\frac{\pi v^2}{2}\,dv\right|$$

(b) The angle of diffraction is small. In practice the limiting factor in the measurement of areas of severe shadow loss is inadequate discrimination by the receiving aerial against reflected rays.

5.2. Practical Considerations

Diffraction occurs in both horizontal and vertical planes, and the former may be neglected only if the width of the obstacle perpendicular to the transmission path is large with respect to the height s. In general, for high buildings this is not so, particularly at points near the building, where s has its maximum value. It would therefore appear that the greatest value of shadow loss due to a high, narrow building may be expressed in terms of an equivalent height equal to half its actual width. On the centre line of the shadow zone the resultant field will be the sum of two equal co-phased components diffracted round the two sides and hence the shadow loss may be reduced by 6 dB.

If, however, the two components are of opposite phase but approximately equal amplitude, cancellation will occur and the shadow loss may be considerably increased. These 'interference zones' were not found to be significant close to the obstacle, where the angle of diffraction is large, but were on occasion to be noticed at greater distances. This effect is discussed in more detail in the Appendix.

In the few instances when it was found possible to carry out measurement runs radially from the transmitter behind the obstacle, it was found that anomalous results were obtained and that the field strength measured was often significantly different for small lateral displacements of the receiving aerial. This was attributed to the presence of these interference zones. It was found that useful information could be obtained only by measurements made along a line at right-angles to the radial from the transmitter.

5.3. Results: Isolated Buildings

5.3.1. Hangar at Croydon Airport (N.G.R. TQ/310638)

Measurements were obtained in the shadow of one of the hangars at Croydon Airport. This building was of a comparatively low height (about 45 ft (13·7 m) a.g.l.) relative to its width. Consequently diffraction was primarily over its roof and no interference zones were observed. Owing to the close proximity of the transmitters the apparent height of the building was very small, the Band V transmitting aerial being optically visible at 30 ft (9·1 m) a.g.l. when d_2 = 130 yds (119 m), and the Band III aerial when d_2 = 200 yds (183 m). Attenuation runs were recorded for distances up to 400 yds (366 m) from the hangar. It was found that for Bands III and V the recorder scale was inadequate to correlate field strength with distance for small values of d_2 and the run was repeated with spot measurements at 2 yds (1·8 m) intervals over the zone where shadow loss was significant. The results obtained are shown in Figs. 4 and 5. It will be seen that there are standing waves, particularly on Band III. These are assumed to be due to inadequate discrimination against reflected rays by the receiving aerial. On Fig. 4 are superimposed theoretical curves of shadow loss calculated from the Fresnel formula for building heights of

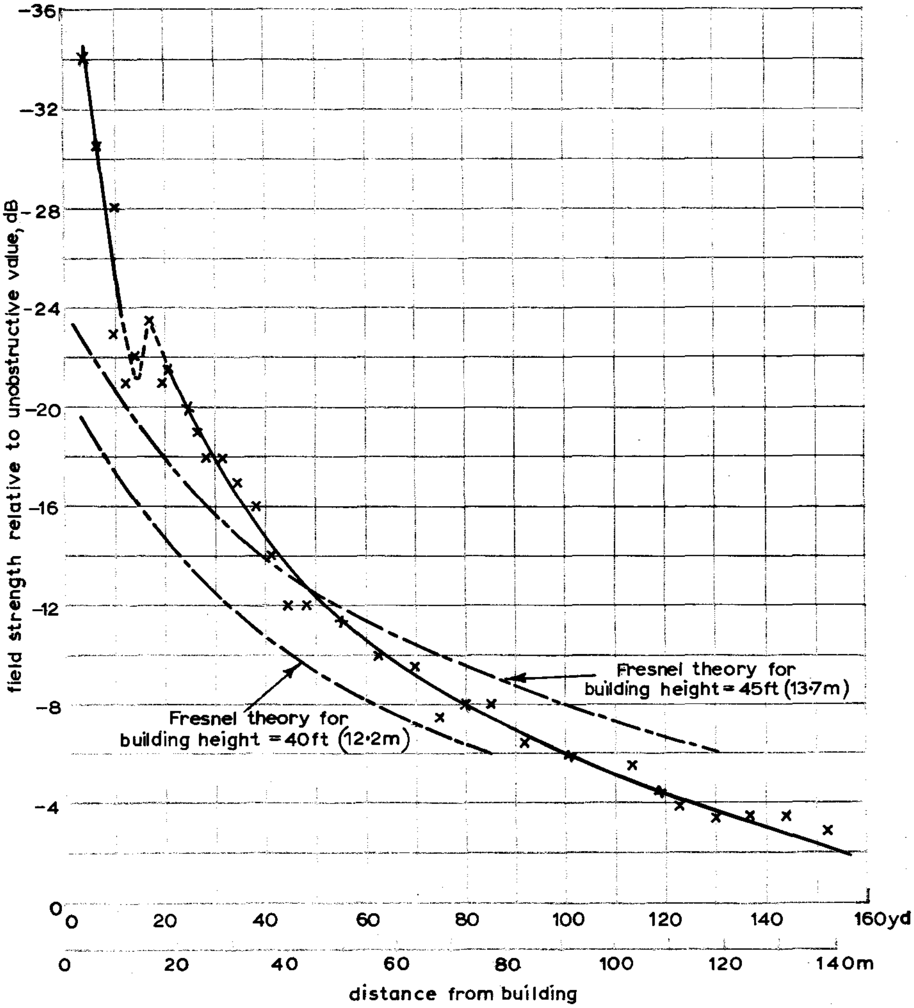

Fig. 4 - Band V: Measured and theoretical shadow loss due to building at Croydon Airport

40 ft (1 ·2 m) and 45 ft (13·7 m), considering only the component of received signal resulting from diffraction over the roof of the building. It will be seen that within the limits of uncertainty regarding the exact height of the hangar, agreement between theoretical and measured values is good for distances greater than 50 yds (46 m) from the building. In the range 20 yds to 50 yds (18·3 to 46 m) a discrepancy occurs which is assumed to be due to cancellation of the direct ray by one reflected from an adjacent hangar. At distances less than 10 yds (9·1 m) the measured shadow loss is again much greater than the theoretical, but at these distances the angle of diffraction is so large that Fresnel theory is no longer applicable. Also at short distances the construction of the hangar is such that a double diffraction occurs.

Referring to Fig. 5, where a best fit curve is drawn through the measured points, the table below relates measured to theoretical shadow loss on Band III at various distances.

TABLE 2

DISTANCE		MEASURED SHADOW LOSS	THEORETICAL SHADOW LOSS
yds	m	(dB)	(dB)
10	9•1	7	22
20	18•3	3•5	18
50	45•7	0•5	11•5

There is thus little relationship between the two sets of values. In fact, the measured shadow loss is insignificant at distances in excess of 20 yds (18•3 m).

Similarly on Band I no significant loss was detectable at distances greater than 10 yds (9•1 m) from the hangar.

5.3.2. Office Block at Morden (N.G.R. TQ/256685)

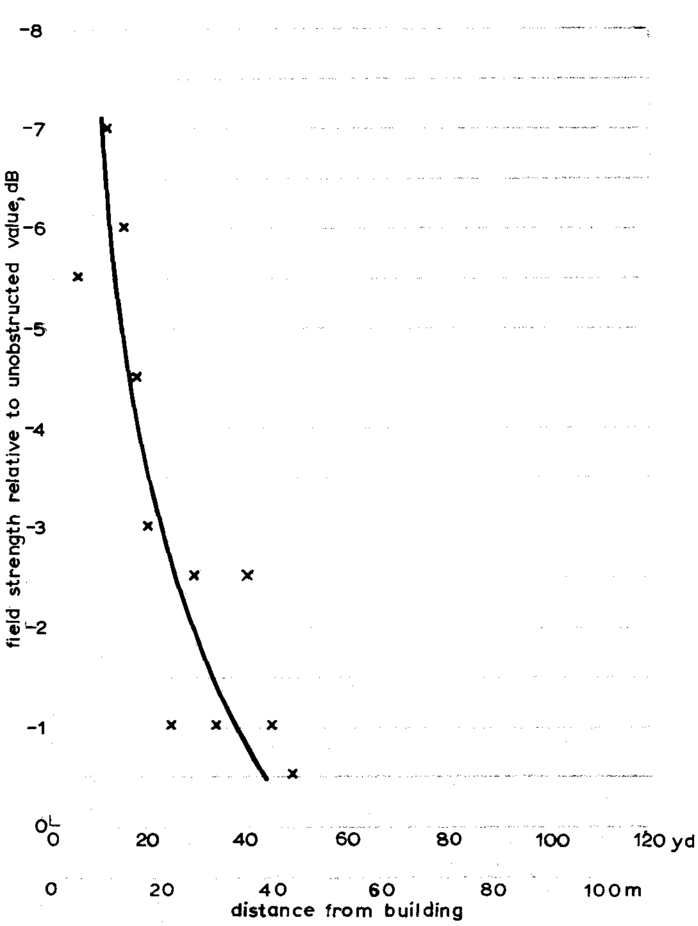

Fig. 5 - Band III: Measured shadow loss due to building at Croydon Airport

Measurements were obtained in the shadow zone produced by the large office block near Morden Underground Station. This building is of particular interest in that it is representative of the most severe type of shadow effect, namely, a large building in a residential area comprising few other buildings more than two storeys high. It is also of interest that, during the period of the measurements, several complaints were received from viewers in the neighbourhood as to the bad 'ghosting' on Band III since this building was erected.

Approximate dimensions of the building were:-

Height	140 ft (42•7 m)
Effective Width	300 ft (91 m)

In this case we may expect, at small distances, equal diffraction will occur round the sides and over the roof. Since, however, the building is less than 6 miles (9•7 km) from the transmitter, the height s decreases rapidly with distance from the building.

Hence at distant points near the centre of the shadow zone, all the incident field may be considered as having been diffracted over the roof of the building.

Figs. 6 and 7 are street plans of the area and show the routes traversed for measurements on Bands I and V, and Band III respectively. The shape of some of the records obtained is shown in Fig. 8. The difficulty of estimating an exact value for the shadow loss will be appreciated.

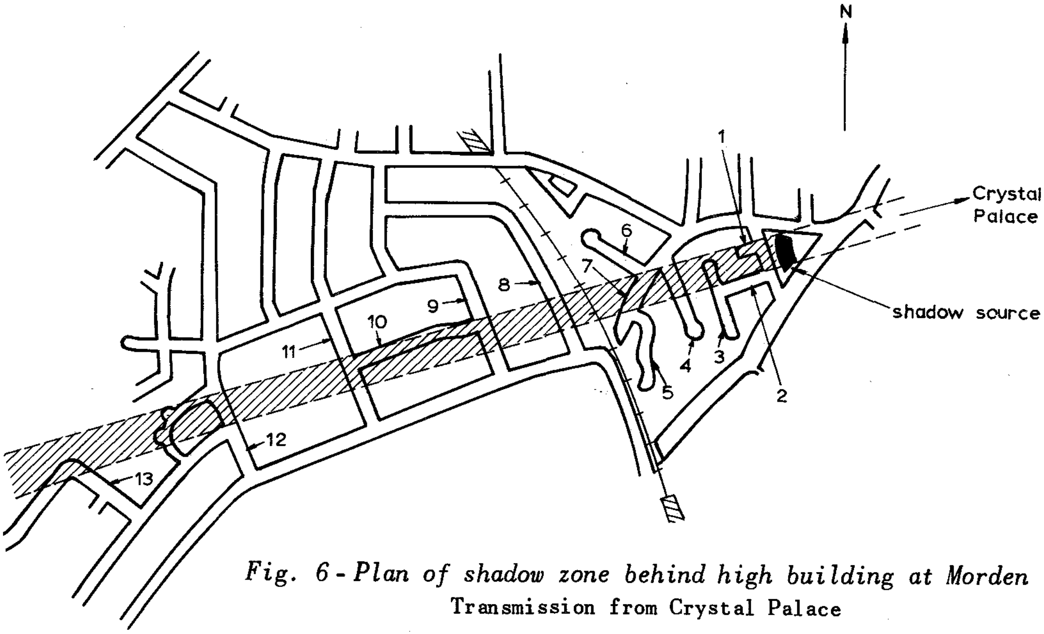

Fig. 6 - Plan of shadow zone behind high building at Morden
Transmission from Crystal Palace

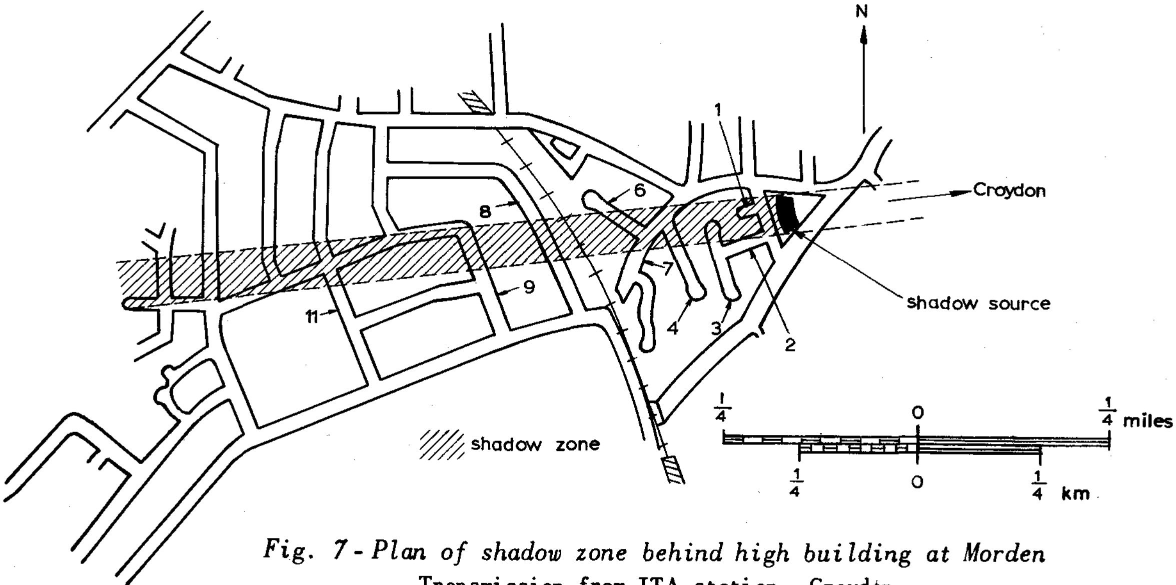

Fig. 7 - Plan of shadow zone behind high building at Morden
Transmission from ITA station, Croydon

Streets visited for field strength measurements

1. Stanley Road
2. Queens Road
3. Camrose Close
4. Cedars Road
5. Hatherleigh Close
6. Woodeville Road
7. Links Avenue
8. Maycross Avenue
9. Arundel Avenue
10. Woodland Way
11. Ashridge Way
12. Monkleigh Road
13. Thursleston Avenue

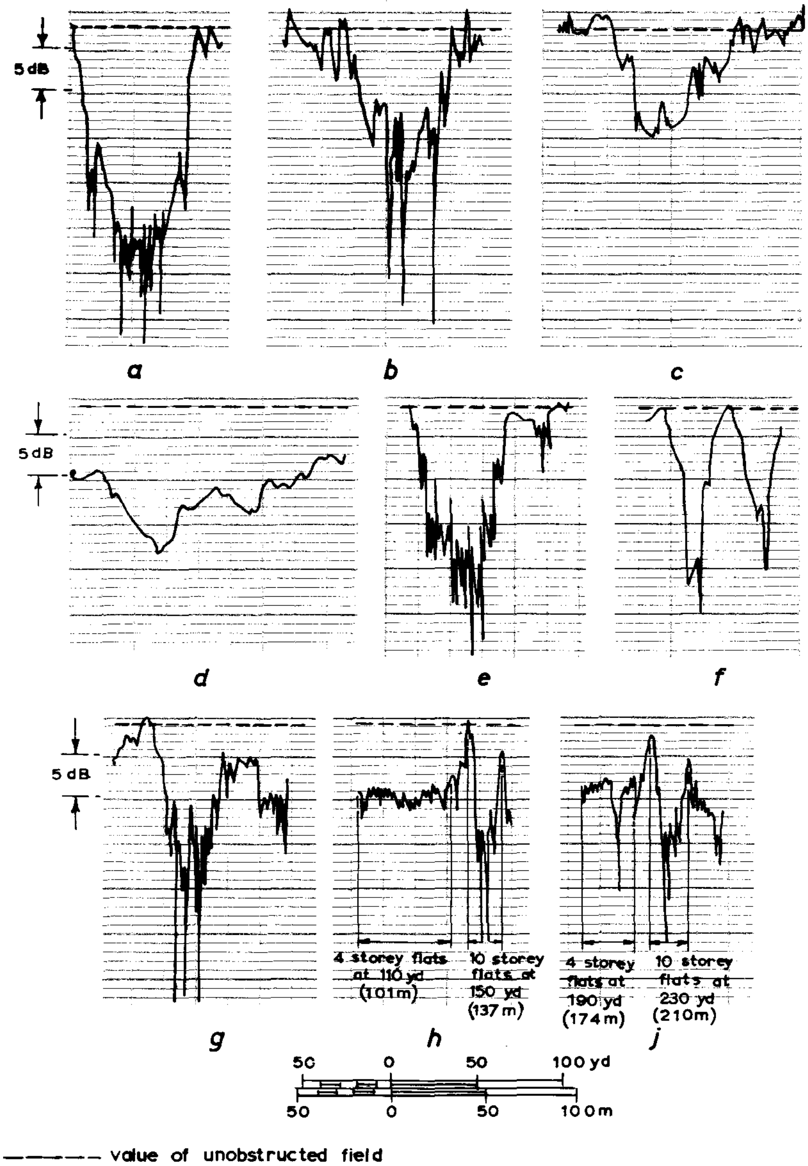

Fig. 8 - Sections from charts of field strength recorded in shadow zones

FIG.	DISTRICT	BAND	STREET	DISTANCE FROM OBSTACLE		HEIGHT OF OBSTACLE	
				yds	m	ft	m
8(a)	Morden	V	Links Av	200-270	183-247	140	42·7
8(b)	Morden	V	Arundel Av	650	594	140	42·7
8(c)	Morden	V	Monkleigh Rd	1200	1097	140	42·7
8(d)	Morden	V	Woodland Way	Measurements made along radial from transmitter		140	42·7
8(e)	Morden	III	Crown Rd	50	45·7	140	42·7
8(f)	Morden	I	Cedars Rd	200	183	140	42·7
8(g)	Hanger Ln	V		450	411	150	45·7
8(h)	Kennington	V		As detailed on fig.			
8(j)	Kennington	V		As detailed on fig.			

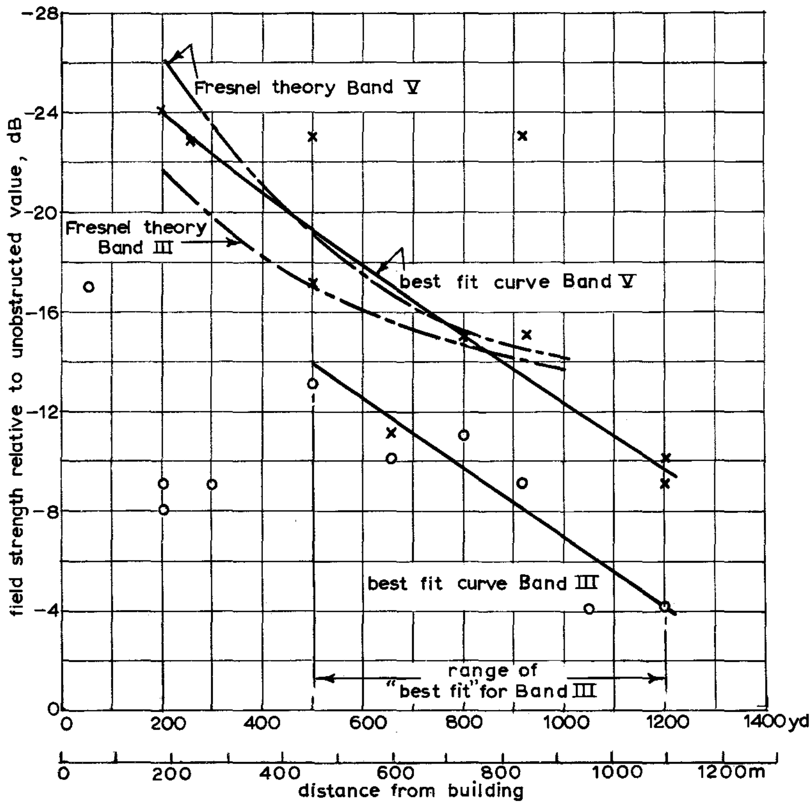

Fig. 9 - Bands III and V: Measured and theoretical shadow loss due to building at Morden

x measured values Band V

o measured values Band III

Fig. 9 represents a plot of shadow loss versus distance for both Bands III and V. Two best fit curves have been drawn through the points. The range of best fit for the Band III measurements is restricted to distances in excess of 500 yds (460 m) from the obstacle, values obtained at shorter distances being considered unreliable due to inadequate receiving aerial directivity. Superimposed are the theoretical curves for the two transmissions, neglecting the effect of any diffraction round the sides of the building. These two curves tend to converge with increasing distance due to the lower transmitter aerial height on Band III. As with the Croydon measurements, the Band V loss as measured agrees well with the theoretical. The measured loss on Band III is much lower than that predicted and the discrepancy becomes greater with increasing distance.

On Band I no losses greater than 8 dB were measured except at 200 yds (183 m), where values of 13 and 17 dB were obtained due to interference effects (see Fig. 8).

5.3.3. Other Buildings

Shadow losses due to several other buildings were measured on Band V only, and the results obtained are as tabulated. The calculated losses assume negligible diffraction around the sides of the buildings.

TABLE 3

BUILDING	HEIGHT		DISTANCE FROM BUILDING		MEASURED SHADOW LOSS	FRESNEL THEORY SHADOW LOSS	REMARKS
	ft	m	yds	m	dB	dB	
Office block at S.W. end of Waterloo Bridge	100	30·5	250-350	230-320	20	16-19	Apparent height of the building is difficult to estimate due to the elevated receiving position on Waterloo Bridge.
Queensway Stores at Crawley	45	13·7	77 165	72 151	11 3	14·5 12	Poor agreement at 165 yds (151 m). Measurements obtained on radial run near the edge of the shadow zone.
Kempton Park Grandstand	60	18·3	135 350	123 320	11 11	17·5 14·5	The 'unobstructed field' was difficult to estimate due to the presence of trees and the value chosen may be too low.
4-storey flat at Kennington	50	15·2	110 190 270	100 174 247	8 7 7	9·5 5 4	Reasonable agreement with theory.
10-storey flat at Kennington	90	27·4	150 230 310	137 210 283	12 12 12	20 16 13	Poor agreement at small distances assumed due to the small effective width (80 ft (24.4 m)) of the building. At 150 yds (137 m) the loss may be expected to be reduced by up to 9 dB, i.e. to 11 dB.
Office block near Hangar Lane	130	40	400 660	365 603	16 17	19 18	Reasonable agreement. Effective width of the building is approx. 200 ft (61 m) and therefore the effect of diffraction round the sides will be significant at small distances.

The results above indicate that in most instances the Fresnel theory is in reasonable agreement with the measured values except for high, narrow buildings, where the effect of diffraction round the sides becomes significant.

5.4. Fresnel Theory Applied to Measurements in the Central London Area

The shadow losses investigated and described above relate to specific single obstructions. In densely built-up areas multiple diffractions will frequently occur and calculation of the overall diffraction loss becomes complicated. In general, however, the greatest diffraction effect will be that of the building nearest to the receiving aerial. To determine whether a reasonable correlation between measured and theoretical shadow losses may be obtained by a consideration solely of a single diffraction, a series of continuous cruise measurements with the receiving aerial at 30 ft (9·1 m) a.g.l. was carried out in the Central London area.

The magnitude of the theoretical losses in this region is indicated by Fig. 10, which shows curves of obstacle height versus distance of receiving point from the obstacle, for three specific values of shadow loss.

It should be emphasized that the results obtained are not necessarily realistic in terms of the standard of service provided, since it is inappropriate to give field strength values at 30 ft (9·1 m) a.g.l. in regions where the average building height exceeds 50 ft (15 m). Also in such areas the absolute field strength may be of secondary importance relative to the ratio of direct to reflected field. The latter can only be determined by subjective assessment of picture quality.

5.5. Results in Central London

To determine the value of 'unobstructed' field strength in the area, the charts were examined for areas of constant high field strength. Thirteen such areas gave field strengths, scaled to the equivalent vision e.r.p., of between 90 and 98 dB(μV/m), with a mean value of approximately 95 dB(μV/m). Lack of reliable information regarding the v.r.p. of the transmitting aerial prevented any correction factor relating field strength to distance from the transmitter from being applied.

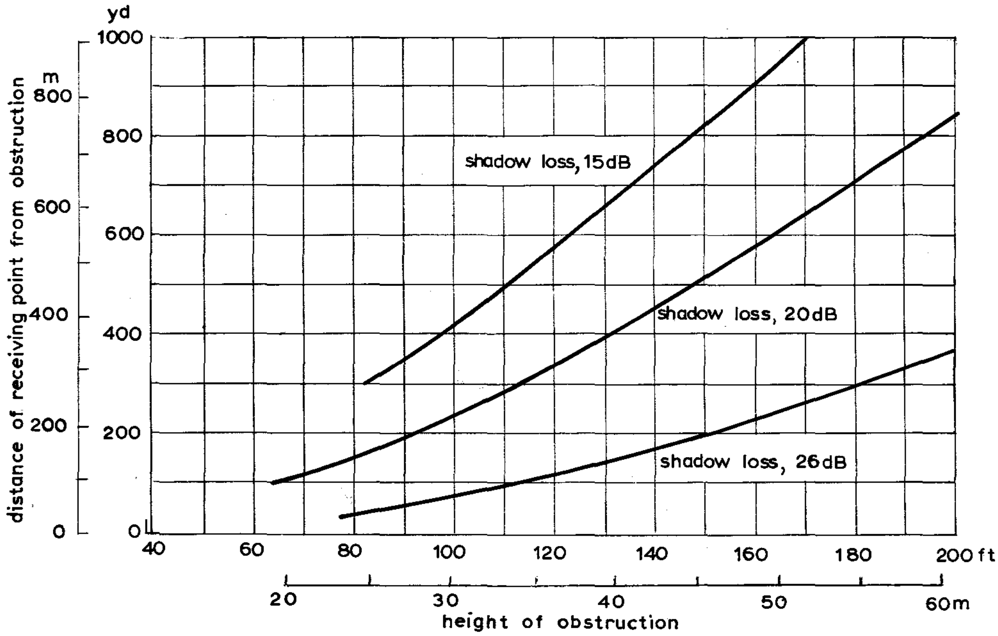

Fig. 10 - Theoretical shadow loss in Central London area

Since all measurements were made using a directional aerial, they were restricted to those obtainable along straight roads, thus eliminating any necessity to re-orient the aerial. Measurements were grouped as below:-

- Group A — Road almost at right-angles to the radial from the transmitter. Measurements made on the side of the road nearer to the transmitter.
- Group B — As for Group A, but measurements made on the side further from the transmitter.
- Group C — Road making an angle between 20° and 60° to the radial. Measurements made on the side nearer to the transmitter.
- Group D — As for Group C, but measurements made on side further from the transmitter.
- Group E — As for Group C, but for angles less than 20° to radial.
- Group F — No particular obstruction within 200 yds (183 m) of the receiving point.

The results obtained are as follows:

TABLE 4

ROAD	GROUP	FIELD STRENGTH REL. TO 'UNOBSTRUCTED' VALUE	CALCULATED FRESNEL LOSS	COMMENT
		dB	dB	
Kensington Road	B	-28	24-30	
Hyde Park (East Carriage Road)	F	-3	0	Any shadow loss probably due to trees.
Park Lane	North End (C)	-23	20-26	Any shadow loss due to trees.
	South End (E)	-8	0	
Constitution Hill	F	-18	0	No obvious obstruction except Buckingham Palace, but the street is wooded.
Birdcage Walk (East)	A	-38	>30	
Birdcage Walk (West)	B	-28	-	Distance of buildings very variable.
The Mall	F	-20	0	No near buildings but the area is wooded.
Regent Street (South of Oxford Circus)	E	-23 to -5	-	Road runs radially. Obstruction caused by buildings at south end.
Portland Place (North)	E-F	-13	-	Road radial to transmitter.
Portland Place (South)		-30	-	

(Cont'd)

Marylebone Road	A	-25	27-30+	Many of the buildings stand back from the road, so Group B may be more appropriate (24-30+ dB).
Regents Park (South Side)	A	-30	27-30+	
Euston Road	B	-33	24-30+	Very high buildings.
Gower Street (North)	E	-23	18-24	
Gower Street (South)	E	-20	18-24	
Oxford Street	B	-23	24-30+	Field strength higher than expected, probably due to multipath reception.
Holborn	B	-30	24-30+	
Newgate Street	B	-25	24-30+	
Threadneedle Street	B	-50	24-30+	Exceptionally high buildings and a narrow street.
Bishopsgate (South and East of Liverpool Street Station)		-38	15-25	
Shoreditch High Street	E	-15	-	Radial to transmitter in parts.
Old Street	A	-33	27-30+	
Denbigh Street	E	-23	18-24	
St. Georges Square West	F	-10	0	Trees towards transmitter.
Belgrave Road	C	-25	24-30	Road is typical of area.
Vauxhall Bridge Road	E	-20	18-24	Very variable field strength.
Albert Embankment (North)	D	-25	24-28	Some very high buildings.
Horseferry Road	A	-30	27-30+	Very high buildings. Field strength values as low as 40 dB(μV/m) recorded.
Victoria Street	B	-33	24-30+	
Whitehall	E	-28		North end radial to transmitter.
Edgware Road (South)	E	-20	18-24	Almost radial to transmitter.
Farringdon Street	E	-13	-	Almost radial to transmitter.
Brompton and Cromwell Roads	A	-28	27-30+	

Theoretical Fresnel shadow losses have been estimated assuming mean building heights of 50 to 75 ft (15 to 22 m) at distances of 20 ft or 50 ft (6 or 16 m) from the receiving aerial, depending upon whether the van was on the side of the road nearer to, or further from, the transmitter. Where possible, a correction is applied to allow for the angle between the road and the transmitter radial. In some instances the wide variation in the heights of the buildings and in their distance from the road does not permit an estimate of Fresnel loss to be made.

Where the measured loss exceeds 20 dB a good correlation with the estimated loss occurs. Estimated losses are not given to more than -30 dB, since for such values angles are no longer small and Fresnel theory is inapplicable. Under such conditions reflections will provide a substantial contribution to the resultant measured field.

6. SHADOW LOSS CAUSED BY FOLIAGE

6.1. General

From the measurements obtained in Central London described in the section above, it may be seen that in several areas a low field strength was attributable to the presence of trees near the receiving point. These measurements were carried out in November when the trees were partially defoliated. To determine whether there is a significant seasonal change in the attenuation caused by trees, comparisons were made of field strengths in wooded regions in early and late autumn.

Five areas were chosen as representing differing degrees of foliage density. Each area also contained a reference region clear of trees. They are described individually below.

1. Road B.290, from the entrance of Kingswood Warren to the junction with the Dorking road (B.2032). This is a region of dense foliage, mostly birch. There is a belt of coniferous trees at a distance in excess of 50 yds (45 m) from the receiving point. The ground profile towards the transmitter is approximately constant over the full length of the area measured, and the western end is clear of trees, enabling an estimate to be made of the shadow loss due to defoliated trees. Measurements were made during cruises with the receiving aerial at 12 ft (3·7 m) a.g.l. and a series of spot measurements was also made at both 12 ft (3·7 m) and 30 ft (9·1 m) a.g.l.

2. Dorking road (B.2032) near the top of Pebble Hill, and in the vicinity of National Grid Reference TQ/217532. This area is rather similar to Area (1) except that the trees overhang the road to a greater degree. There are, however, fewer coniferous trees in this area. A series of spot measurements was made with the aerial at 12 ft (3·7 m) and 30 ft (9·1 m) a.g.l.

3. The Brighton road between Burgh Heath and Kingswood Warren entrance. The northern half of this area is densely wooded with many overhanging branches. The density of traffic did not permit any measurements to be obtained at aerial heights other than 12 ft (3·7 m) a.g.l.

4. Road A.240 between Ewell and Drift Bridge. This road runs at right-angles to the transmitter radial, and has a single line of trees on either side.

5. The A.243 Leatherhead to Hook road from the Leatherhead town boundary to Telegraph Hill. An extensively wooded area (Ashtead Common) is situated on the bearing of the transmitter, but the nearest trees are not, in general, closer than 20 to 50 yds (18 to 45 m) from the receiving point. Cruises were made at aerial heights of 12 ft (3·7 m) and 30 ft (9·1 m) a.g.l., the latter series being reproduced in Fig. 1.

6.2. Results

Band I field strength measurements were made in Areas (4) and (5) and no shadow loss due to foliage was detectable. Median shadow losses obtained on Band III and Band V are as tabulated.

TABLE 5

AREA	SHADOW LOSS DUE TO EFFECT OF FOLIAGE ALONE (dB)		ESTIMATED SHADOW LOSS DUE TO PRESENCE OF DEFOLIATED TREES (dB)	
	Receiving Aerial at 12 ft (3·7 m) a.g.l.	Receiving Aerial at 30 ft (9·1 m) a.g.l.	Receiving Aerial at 12 ft (3·7 m) a.g.l.	Receiving Aerial at 30 ft (9·1 m) a.g.l.
BAND III				
(1)	2-3	4	8-9	4-5
(2)	2	2	3-4	No comparison measurements obtained in open country
(3)	0	Not measured	No open country comparisons obtained	
(4)	0	$\leqq 3$	Negligible	Negligible
(5)	1½	3	No estimate possible (see text)	
BAND V				
(1)	$\leqq 2$	3-4	$\simeq 15$	$\simeq 15$
(2)	1	3-4	14	9
(3)	2½	Not measured	No open country comparisons obtained	
(4)	2½	2½		$\leqq 3$
(5)	1	2	No estimate possible (see text)	

In so far as foliage in early autumn can be considered as representative of trees in full leaf, Table 5 indicates that the attenuation due to foliage alone is not significantly greater on Band V frequencies than on Band III. The areas of greatest loss, (1) and (2), are unlikely to be encountered frequently in practice, the branches of the nearest trees being within 5 to 10 yds (4·6 to 9·1 m) of the receiving aerial.

The loss due to foliage appears to be greater at a receiving aerial height of 30 ft (9•1 m) a.g.l. than at 12 ft (3•7 m) a.g.l. Presumably this is because at the greater height the incident signal traverses the main bulk of the foliage, whereas at lower aerial heights the obstruction is caused by the tree-trunks and undergrowth. Since much of the latter is evergreen, the opacity will be more nearly constant throughout the year.

Where it has been possible to estimate the attenuation caused by the trunks and branches of the defoliated trees, the loss appears to be significantly greater at u.h.f. The difficulty in differentiating between field strength attenuation due to trees and to terrain features is emphasized by reference to the charts comprising Fig. 1. Between points (a) and (b) the height of the road upon which the cruise was made does not vary by more than ± 20 ft (6•1 m). Field strength variation in this region is due to a combination of attenuation through trees and the presence of a small knoll rising to a height of approximately 80 ft (24•4 m) above road level at a distance of ½ mile (0•8 km). Neglecting standing wave pattern changes, the overall field strength variation over this region is 2 dB on Band I, 10 dB on Band III, and 25 dB on Band V. Even in such a relatively flat area it is not considered feasible to separate the relative attenuations caused by the two factors of trees and terrain.

7. CONCLUSIONS

7.1. Shadow Loss due to Buildings

The results obtained indicate that a good approximation to the attenuation produced by buildings at u.h.f. may be obtained by application of Fresnel optical diffraction theory. The measurements obtained in the Central London area indicate that it is usually sufficient to consider solely the loss due to the obstacle nearest to the receiving point. Examining the table of London results in detail, the only anomalous results appear to be (a) where trees cause attenuation in otherwise clear areas, and (b) in the Bishopsgate-Shoreditch region, where the field strength is considerably lower than estimated from consideration of local screening. It is thought that this region is within the shadow zone caused by the exceptionally high buildings in the Leadenhall Street-Fenchurch Street district. By Fresnel theory a 100 ft (30•5 m) high building in Leadenhall Street would cause a shadow loss of 20 dB at the centre of the zone measured.

In view of the considerable shadow losses caused by buildings at u.h.f., discretion must be applied when measuring field strength in densely built-up areas. Obviously, in considering the needs of viewers living in an area 'shadowed' by high buildings, measurements must be obtained to evaluate the likely standard of service. In general, however, it appears unrealistic to give field strengths at 30 ft (9•1 m) a.g.l. in regions where the average building height is greatly in excess of this value.

It is recommended that for the purpose of field strength surveys some arbitrary limits should be set wherein spot measurements should not be made unless special conditions merit it. Such limits might be:-

(a) Not less than 50 yds (45 m) behind a three-storey building.

(b) Not less than 100 yds (91 m) behind a building of more than three storeys.

A distinction must be made between the condition where a high building overshadows a number of smaller ones, and that occurring normally at the centre of a town, where any receiving aerials would be mounted at heights much in excess of 30 ft (9·1 m) a.g.l. In the former, picture quality assessments may also be required, since in shadow zones the existence of adequate field strength is no guarantee of the provision of an adequate service. The ambient field strength in town centres may often be more realistically assessed by extrapolation of results obtainable in less densely built-up areas in the near vicinity.

7.2. Field Strength Attenuation due to Trees

The results indicate that the presence of trees near the receiving point adds considerably to the path attenuation at u.h.f., and to a smaller extent at Band III frequencies. Foliage appears to be of secondary importance in determining the magnitude of the attenuation, which is therefore not expected to vary significantly throughout the year. Further measurements are required in late spring to establish whether those obtained in early autumn are fully representative of trees in leaf, and to determine whether visible picture 'flutter' is caused by the effect of wind in foliage. In view of the difficulty of dissociating attenuation due to trees from field strength variations due to terrain, the values given in this Report should be considered as no more than representing the magnitude of the losses to be expected.

8. REFERENCES

1. 'Crystal Palace Band V Field Strength Survey', Research Department Report No. K-141, Serial No. 1959/25, p. 3.

2. Van Witngaarden, A., and Scheen, W.L., Report R49 of the Computation Department of the Mathematical Centre at Amsterdam, published by N.V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam, 1949.

APPENDIX

Interference Fringes in the Shadow Zone

A few of the records obtained from field strength measurements behind isolated buildings indicated the existence of a standing wave pattern with pronounced minima approximately symmetrically disposed about the centre of the shadow zone. Examples are shown in Fig. 8(e), (g), (h) and (j). In view of this symmetry the pattern was considered to be due to a series of interference fringes caused by interaction between wavefronts diffracted around the two sides of the building.

Fig. 11 represents the plan view of a building having width DE normal to the transmitter. It is assumed that the building is sufficiently far from the transmitter for the incident wavefront to be considered as plane, and hence the phase at D is identical with that at E. It is further assumed that the height of the building is sufficiently large to ensure that a negligible proportion of the field at 30 ft a.g.l. in the shadow zone is contributed by diffraction over the top of the building.

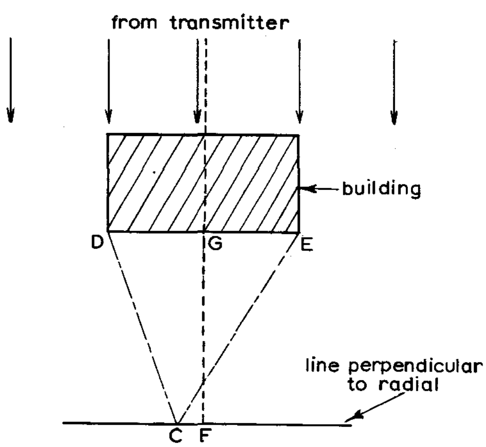

Fig. 11 - Plan view of obstacle in transmission path

At all points in the shadow zone the resultant field will be the vector sum of the components received from D and E (which may be regarded as secondary co-phased sources). As the path difference on the perpendicular bisector GF is zero, the resultant field on this bisector will have twice the magnitude of that due to either source alone.

Suppose, however, that at point C:

$$EC = DC + n\frac{\lambda}{2}$$

where n is an odd integer and λ is the wavelength of the transmission. The two components are now in antiphase, and cancellation will occur, producing a series of interference fringes. For large values of λ and of n the angles of diffraction at D and E are no longer approximately equal and hence the two components of field at C are not of the same magnitude.

Such interference fringes were not often observable in the shadow zones investigated, because at the more distant points the effective height of the buildings was seldom large with respect to their width. At points close to the building where this condition was satisfied, the directivity of the receiving aerial was often inadequate to discriminate against standing wave patterns caused by spurious reflections.

ALG

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